Helping the designer to choose his software: Comparative analysis of human modeling tools

Mathieu Delangle[a], Emilie Poirson[a]
a. *Institut de Recherche en Communications et Cybernétique de Nantes*

Résumé :

Les outils numériques de modélisation humaine permettent de simuler des tâches réalisées par un humain dans un environnement virtuel et fournissent de nombreux indicateurs utiles dans les domaines de l'ergonomie, de la conception universelle et de la représentation virtuelle de produits. Les derniers développements dans ce domaine sont en termes d'apparence, de comportement et de mouvement. Avec l'augmentation considérable de la puissance des ordinateurs, certains de ces programmes intègrent désormais un nombre de détails importants rendant le résultat de plus en plus proche de situations réelles. Avec les différences en termes de performances, de qualités, de limites, choisir un logiciel adapté devient de plus en plus compliqué dans ce large éventail de possibilités. Dans ce contexte, nous proposons d'étudier et de comparer la plupart des logiciels de modelage humain disponibles sur le marché, et ainsi fournir un outil pour aider le concepteur à choisir le logiciel le mieux adapté à ses besoins.

Abstract :

Digital Human Modeling tools simulate a task performed by a human in a virtual environment and provide useful indicators for ergonomic, universal design and representation of product in situation. The latest developments in this field are in terms of appearance, behaviour and movement. With the considerable increase of power computers, some of these programs incorporate a number of key details that make the result closer and closer to a real situation. With the differences in terms of performance, qualities, limitations, the choice of the tool becomes complicated in this wide range of possibilities. In this context, we propose to study and compare the most human modelling software available on the market, and thus provide an aided decision tool to help the designer to get the most adaptable tool.

Mots clefs : **Digital Human Modeling ; Comparative analysis ; Aided decision**

1 Introduction

In the recent decades, emerged commercial software based on numerical models of man : the virtual human [3]. The Digital Human Modeling Software (DHMS) have been introduced in industry firstly to facilitate a faster design process [13]. With the increasing of computer power, the use of DHM software became unavoidable in the life cycle of products, where the design has to answer to end-user expectations, including their need for usability [12]. With an iterative process of product evaluation, the correction and adjustments are quicker with this sort of tools [6]. As in all categories of software package, the quality and accuracy increase continuously, to meet the demand of industrials and researchers ([7],[11]). The proliferation of tools becomes problematic for the designer who has sometimes a multitude of functions that are not suitable for his application case.

In our study, we propose a decision-aided tool to choose a DHM software. The first step of our study consisted in listing all the comparable software and to selection the comparison criteria. Then a list of indicators is proposed, in three major categories : degree of realism, functions and environment. Based on software use, literature searches [2] and technical reports ([4], [5], [14], for example), the table of indicator is filling and coding from text to a quinary format, in order to performed comparative analysis. The first section presents the characteristics of the selected DHM tools and the design methodology of the database. The second section deals with the list indicators and both filling and coding the comparison table. The last part presents the results and the outlooks of the study.

2 DHM tools comparison : methodology

An exhaustive list of 32 commercially available 3D modeling software, computer programs used for developing a mathematical representation of any three-dimensional surface of objects was determined (step 1, Figure 1). A part of these tools defined as generic modelers (ie software allowing purely artistic entities modeling without real anthropometric approach) have been removed and a list of reachable human modelers was obtained (step 2, Figure 1). For example, Rhinoceros is a NURBS-based 3D modeling software, commonly used for industrial design, architecture, marine, jewelry design but not manikin design. It would have been inappropriate to keep them in the comparison. The same applies to the other generic modeler (not human dedicated design) as Blender, True SpaceMaya, 3D studio Max, Lightwave, (...), Pro/Engineer. The twelve DHM software selected for our study are (Figure 2) Jack (Siemens), Ramsis (Human Solutions), HumanCad (Nexgen Ergonomics), 3DSSPP (University of Michigan), Poser (Smith Micro), MakeHuman (freeware), Anybody (Anybody Technology), Catia (Dassault Systemes), Daz Studio (DAZ 3D Inc), Quidam (N-Sided), Santos (University of Iowa), Sammie (Sammie CAD Ltd).

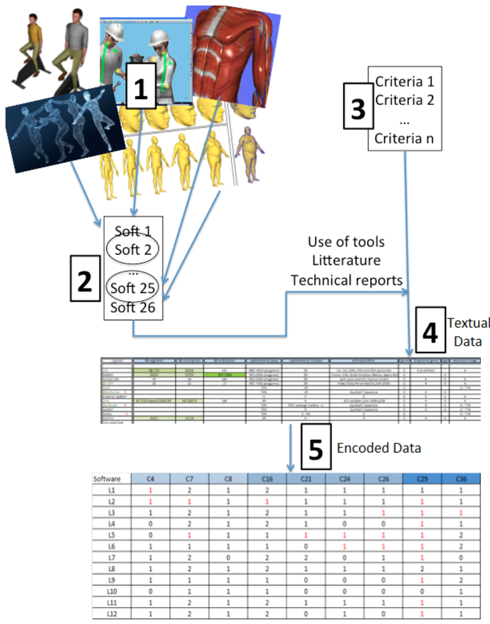

FIGURE 1 – SYNOPTIC OF THE METHODOLOGY OF EVALUATION OF PRODUCTS

The step 3 (Figure 1) is then to collect and select the differentiating criteria to evaluate the software presented just above.

3 Comparison table

3.1 Criteria

A list of indicators is defined to perform an objective comparison between all software (Table 2). To generate this list, websites and forums about DHM tools are analyzed as technical manuals of Santos [1], Ramsis [17], Jack [15], 3DSSPP [16] for example. All the menus given a choice of functions are explored. The criteria are classified in 3 main classes :

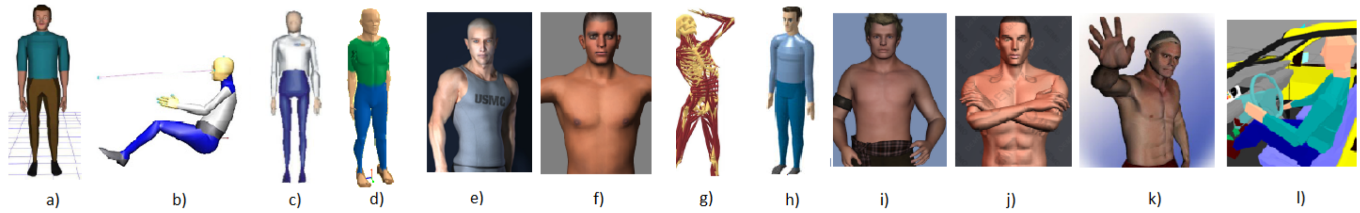

FIGURE 2 – MANIKIN OF JACK (a), RAMSIS (b), HUMANCAD (c), 3DSSPP (d), MANIKIN OF POSER (e), MAKEHUMAN (f), ANYBODY (g), DELMIA (h), MANIKIN OF DAZ (i), QUIDAM (j), SANTOS (k) AND SAMMIE (l)

TABLE 1 – CRITERIA OF THE 3 CLASSES

	Class 1	**Class 2**	**Class 3**
	Degree of realism	Functions	Environment
1	Nb of segments	Mannequin data base	Objects creation
2	Nb of joints	Posture data base	Nb Mannequins/environment
3	Degree of freedom	Posture modification	Environment animation
4	Physical limits	Action data base	Constraint mannequins/objects
5	Skin representation	Action modifications	Constraint/mannequins
6	Muscles representation	Animation	Import environments
7	Anthropometry	Response to stress	Objects data base
8	Gender	Static analyses	Intuitiveness of interface
9	Gender graduation	Dynamic analyses	
10	Age	Field of view	
11	Face expression	Reach envelop	
12	Complements	Fatigue model	
13	Dynamic of complements	Collision detection	
14		Import/Export Format	
15		Motion capture	

• Class 1 : Degree of realism This class is used to compare the criteria concerning anything that may be relevant in assessing the degree of realism of the software (reliability of the representation of the model and its movements or respect of human physical constraints, for example).

• Class 2 : Functions This class is very important for ergonomic and fatigue studies. It is associated with existing functions in the software to perform some analysis on the virtual model (Reach envelop or Fatigue model for example).

• Class 3 : Environment Includes criteria for the creation and manipulation of the environment available in software.

The criteria 1 from the first class will be called C1.1. If the criteria are mostly obvious, definition is to be precise for others. Physical limits (C1.4) stands for taking into account the physical constraints of articulations as knee and elbow. The Gender graduation (C1.9) stands for the the evolution of body forms, more or less pronounced. Complements (C1.12) are all the personalization of the manikin with clothes or accessories, and their movement during an animation (Dynamic of complements - C1.13).

Few simplifications on the criteria were done. Defining the number of degrees of freedom, joints and segments seemed confusing for a non expert-user. Criteria C1.1, C1.2 and C1.3 have been gathered under the label "Accuracy joint chain", C1.1. Secondly, the difference between motion and animation is low and not always understood. Criteria from C2.4 to C2.6 were therefore aggregated. Finally, in the data of environment, only the first, very important for ergonomic and the last one (essential to reach

Table 2 – CRITERIA OF THE 3 CLASSES

	Catégorie 1 Degré de réalisme	**Catégorie 2** Fonctions	**Catégorie 3** Environnement
1	Nombre de segments	Base de données de mannequins	Création d'objets
2	Nombre d'articulations	Base de données de postures	Nb mannequin par environnement
3	Degrés de liberté	Modification de la posture	Annimation de l'environnement
4	Limites physiques	Base de données d'actions	Contraintes mannequin/environnement
5	Représentation de la peau	Modification des actions	Contraintes entres mannequins
6	Représentation des muscles	Animation	Importation d'environnements
7	Anthropométrie	Réponse aux efforts	Base de données d'objets
8	Genre	Analyses statiques	Intuitivité de l'interface
9	Graduation du genre	Analyses dynamiques	
10	Age	Field of view	
11	Expression faciale	Enveloppe d'atteinte	
12	Compléments	Modèle de fatigue/ergonomique	
13	Dynamique des compléments	Detection de collisions	
14		Format d'importation/exportaion	
15		Capture de mouvement	

all trades and new applications) were kept. With the different transfer format, even if the software doesn't allow to create an environment, the manikin can be included in an existing one in another tool. It seems to us not primordial for this first study. The list of criteria has now 25 items.

3.2 Filling method (step 4, Figure 1)

A table containing software and the 25 criteria is built. Based on software use, literature searches, manual study and by contacting users of different softwares, each cell of this table is filled with textual data. This step, long and fastidious was led with rigor and completeness. The different scales were not pre-defined, ignoring a priori which information we will collect.

3.3 Coding of criteria (step 5, Figure 1)

To perform a comparative analysis, it is essential to formalize textual data contained in the table. Criteria (Table 2) were split in 3 categories. The first one is the binary criteria, answering yes or no for the presence of the function (criteria C1.8, 1.10, 1.13, 2.7, 2.9, 2.10, 2.11, 2.13, 2.15). The second class contains those evaluated on a 5 points scale, quantifying the criteria (0-criterion not satisfied, 1-criterion partially satisfied, 2-criterion moderately satisfied, 3-criterion rather well satisfied, 4-criterion completely satisfied, criteria C1.1, 1.4, 2.1, 2.2, 2.4, 2.8, 3.11). The last category is also a quinary scale about the precision of data : for example, the skin representation can be inexistant (0), existing but not very modifiable (1) to fully configurable (4). That is the case for C1.5, 1.6, 1.7, 1.8, 1.9, 1.12, 2.3, 2.9, 3.1.

4 Tools for decision support

After coding data from text to a quinary format for the entire comparison table, multivariate statistical analysis (Principal Components Analysis and Hierarchical Ascendant Classification) are used to perform a decision tree (Figure 3 on the right). This dendogram allows to divide software into several homogeneous groups and so identify different classes of tools depending on some essential discriminant criteria.

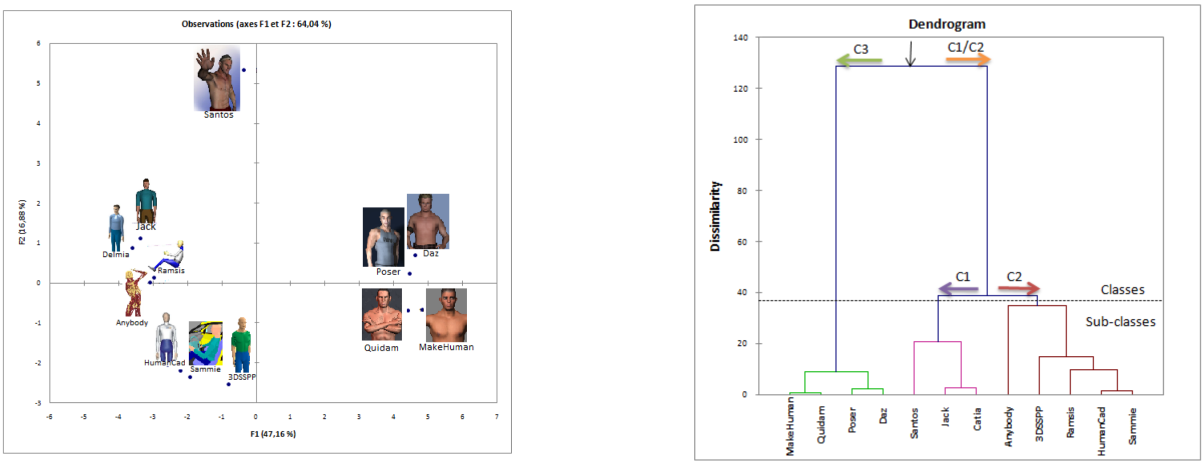

FIGURE 3 – INDIVIDUALS REPRESENTATION INTO A TWO-DIMENSIONAL PLANE 5 (LEFT) and HIERARCHICAL TREE OF SOFTWARE (RIGHT)

4.1 Principal Component Analysis

The Principal Component Analysis (PCA) is used to reduce the dimensions of the space allowing a representation of the proximity between individuals and variables and to find the underlying dimensions. The matrix was analyzed using standardized PCA. The two first factors represent 64,04% of variability : only two factors are considered to represent the differences between the software. In our case (Figure 3 on the left), the first Principal Component is mainly composed of criteria based on the realism of the manikin, including its movements. Software are clearly in 2 groups on this axis : a first on the right side of the graph, composed of Catia/Daz/MakeHuman/Quidam, software allowing DHM simulation with an high quality graphics rendering. The left group has a littler graphical definition but with an higher number of analysis functionality. The second Principal Component is correlated to criteria based on analytic tools as collision detection or fatigue model. This confirms the intuitive classification of criteria performed.

4.2 Hierarchical Ascendant Classification

In order to provide a partition of the software and to define groups, similar from an analytic point of view, a hierarchical ascendant classification (HAC) [9] has been done. The principle of HAC is to build a hierarchical tree (dendrogram, Figure 3 on the right), which shows the level of each aggregation according to the dissimilarity between the products. The parameters of the method are the definition of the distance for computing the dissimilarities and the linkage rule, computed through the Ward criteria.

From the hierarchical tree and by identifying what are the main discriminating criteria, it is possible to define a protocol to determine from minimum questions, what is the best suited software to the expected use. Some criteria (variables) identified through the PCA and HAC are grouped together in the form of questions to guide quickly the search towards a specific group of software. Other criteria are then explicitly evaluated allowing accurate selection of the software. Five questions (regarding the "capacity to perform analysis", "realism of mannequin", "Animation of mannequin", "ages of mannequin" and "human appearance of mannequin"), involving some discriminants criteria, allow to quickly select corresponding software. These questions are encoded in a friendly interface allowing an easier selection of the adapted software.

Conclusion and perspectives

This paper presented a methodology allowing to perform a decision making tools to help the designer to choose his software. An application of this method comparing twelve digital human modeling software has been presented. From a table including characteristics of software through al list of 25 comparison criteria, Principal Components Analysis and Hierarchical Ascendant Classification were used to build a decision tree. Finally, a recommender with a visual perceptions based interface is offered to the designer to help him to choose the "perfect" product.

The human modeling is essential in the lifecycle of the product, allowing a very good communication between all the actors of the life of product. Integration of an adapted DHM tools in the product life cycle allows to perform both a more efficient design and more sustainable products. The aim of the presented procedure is the conception of a tool allowing to the designer to quickly determine what are the types of solutions that best suit his needs. In our study, the tools are dedicated to helping the designer to find the most suitable software. It is understood that this is only an example to illustrate the method (the number of software not being very important the problem could be tackled manually). However, the methodology can be adapted to all kinds of applications, for example in the design of products. Indeed, software of our study may be replaced by a sample of a product randomly generated (Monte Carlo's method...) and also evaluated using criteria (height, width, color, texture, materials...). Thus, using our method, the discriminating criteria may be identified and automatically encoded in the decision making tools allowing to offer to the designer a sample of shapes adapted to their needs, by answering some questions.

The following this study intends to use optimization tools for multi-disciplinary problem solving, such as interactive genetic algorithms [8](or evaluation function of individuals is humanly made, not computed). This would also be the case for products or differences are mostly perceptual and why the differences are difficult to explain[10], [18]. Furthermore, the relevance of the method still to be evaluated to verify the efficiency of the questionnaire and the satisfaction of users with the set of selected software.

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